THE Tay Bridge, at Dundee, was opened on Friday, in presence of a large and distinguished company.

TWO Reports come to us from Scotland—one on the Glasgow Industrial Museum, and the other on the Dundee Free Library. From the former we are glad to see that, under the energetic curator, Mr. James Paton, F.L.S., the Glasgow Museum is gradually becoming worthy of the second city of the kingdom. Many important additions are being made to the well-arranged museum, with which, we see, have been incorporated the Corporation Galleries of Art. We trust the successors of "Bailie Nicol Jarvie" and his contemporary councillors will exercise a wise liberality and speedily raise their museum to the position it ought to occupy. From the Report of Mr. Maclauchlan we are pleased to see that scientific works are in considerable demand among the busy people of enterprising Dundee. The interesting museum, also, is gradually becoming possessed of that complete collection of the Arctic fauna which strangers naturally look for in the museum of the chief seat of the whaling trade.

IN the *Annalen der Hydrographie* we notice the account of a group of three islands discovered by Capt. Caller in 1877 on the north-west coast of Australia. These islands, which in their highest point do not rise more than thirty feet above the level of the sea, are covered with a thick deposit of guano, containing an unusual amount of ammonia and phosphates. On account of their nearness to the continent these valuable deposits will probably play an important part in the agricultural development of Australia.

ON October 4 last we gave an account of the post-mortem examination of a white whale (*Beluga*) that died after a few days' residence in a tank at the Westminster Aquarium. Mr. Farini then commissioned Zack Coup to obtain three more and bring them over from Labrador. They were packed each in a separate box lined with sea-weed, and four men were engaged to relieve one another in throwing water over the heads of the animals during the entire voyage. On Tuesday, May 27, they arrived at Liverpool, when one specimen was sent to Blackpool, one to Manchester, and one was brought under the personal care of Mr. Farini and Mr. Carrington, the naturalist of the Aquarium, to Westminster. This London specimen is 13ft. 6in. long, and arrived in apparently good condition. On Friday it was found requisite to "sling" it in order to remove an eel that had become entangled in its right flipper, when its quick sight in trying to avoid the sling was noticed with interest. The legs of a man sitting on the edge of the tank it carefully avoided, but it did not seem to mind the presence of those standing round. After the whale had been in the tank four days an indication of malaise and apparently of some accident having occurred attracted the careful attention of those who had charge of it. It was then ascertained the specimen was a female, and was for a while a subject of interest to physiologists especially.

A NEW improvement in the microscope is reported from Germany. Herr I. von Lenhossék has constructed an apparatus which permits no less than sixty microscopical preparations being observed in immediate succession, without the trouble of changing the slides and readjustment of the object-glass. Its construction is similar in principle to that of the well-known revolving stereoscopes, and the inventor has given the new apparatus the name of "polymicroscope."

UPON the occasion of unveiling the statue of Giordano Bruno, which will take place at Rome on February 19, 1879, a new edition of his works will be published. They are being reprinted at the expense of the Italian government.

THE Vienna Academy of Sciences held its annual public session on May 29, in the presence of representatives of the Court and Government. After the announcement of the various prizes and reports on the progress in the several sections of the Academy, Prof. Hann delivered an address on the "Problems of Modern Meteorology."

AN Ethnographical Exhibition, organised by the Anthropological Society of Paris in an annexe to the Trocadero, was opened on May 31. M. Teisserenc de Borg, Minister for Commerce and Agriculture was present on behalf of M. Bardoux, the Minister of Public Instruction, and declared the exhibition open. The addresses were delivered by MM. Quatrefages, Henri Martin, the president of the Society, and Dr. Broca. This exhibition is an extension of the Provisional Museum established for some months at the Palais de l'Industrie, in the Champs Elysées.

WE noticed at the time that M. Jules Simon, when French Minister for Public Instruction, had opened in the buildings of the Ministry, a provisional Pedagogical Museum, but a change having supervened in the Cabinet the scheme was dropped. It will, we learn now, be revived by M. Bardoux, who has asked special credit for that purpose from the Chamber of Deputies.

THE electric-light display in the Paris streets and thoroughfares is becoming one of the attractions of Paris. Eight electric lamps have been placed in the Place de l'Opéra, twenty-four others in the Opera Avenue, and eight more on the Place du Théâtre Français. Six lamps were lighted for the first time on June 1 on the part of the Palais Bourbon facing the Place de la Concorde. We should notice also the private illumination of the Grands Magasins du Louvre, about seventy lamps; Belle Jardinière, eight; Concert de l'Orangerie des Tuileries, twenty; and the Hippodrome, thirty-two. This last illumination, being in a closed building, cannot be viewed from the streets. All these illuminations are made by the Jablochkow candles. An electric lamp has been placed also on the top of the Trocadero Palace.

WE notice that the list of jurors for the Paris Exhibition has been gazetted.

THE last number of the *Journal* of the Society of Arts contains a valuable paper, recently read by Mr. J. M. Thomson, F.C.S., before the Society, on the Position of Chemistry in a System of Technical Education, as illustrated by some of its Applications. We are glad to see the Society turning its attention to a subject of such great importance.

THE additions to the Zoological Society's Gardens during the past week include a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mr. J. Farmer; a Geoffroy's Cat (*Felis geoffroii*) from Uruguay, presented by Mr. Ronald Bridgett; a Brazilian Caracara (*Polyborus brasiliensis*) from South America, presented by Miss Amslie; a Tamandua Anteater (*Tamandua tetradactyla*) from South America, deposited; a White-eared Bulbul (*Pycnonotus leucotis*) from North-west India, received in exchange; four Temminck's Tragopans (*Ceriornis temminckii*), bred, a Yellow-footed Rock Kangaroo (*Petrogale xanthopus*), an Axis Deer (*Cervus axis*), born in the Gardens.

THE REDE LECTURE[1]

WHEN, about two years ago, news came from the other side of the Atlantic that a method had been invented of transmitting, by means of electricity, the articulate sounds of the human voice, so as to be heard hundreds of miles away from the speaker, those of us who had reason to believe that the report had some foundation in fact, began to exercise our imaginations in picturing some triumph of constructive skill—something as far surpassing Sir William Thomson's Siphon Recorder in delicacy and intricacy as that is beyond a common bell-pull. When

[1] Given at Cambridge by Prof. Clerk-Maxwell, F.R.S., May 24, 1878 Subject—"The Telephone."

at last this little instrument appeared, consisting, as it does, of parts, everyone of which is familiar to us, and capable of being put together by an amateur, the disappointment arising from its humble appearance was only partially relieved on finding that it was really able to talk.

But perhaps the telephone, though simple in respect of its material and construction, may involve some recondite physical principle, the study of which might worthily occupy an hour's time of an academic audience: I can only say that I have not yet met anyone acquainted with the first elements of electricity who has experienced the slightest difficulty in understanding the physical process involved in the action of the telephone. I may even go further, and say that I have never seen a printed article on the subject, even in the columns of a newspaper, which showed a sufficient amount of misapprehension to make it worth preserving—a proof that among scientific subjects the telephone possesses a very exceptional degree of lucidity.

However, if the telephone has something to say for itself, it would seem hardly necessary for me to take up your time with any tedious introduction. It is unfortunate, however, that up to the present time the telephone has kept all his more perfect utterances to be whispered into the privileged ear of a single listener. When he is older, he may get more accustomed to public speaking, but if we force him, in his present immature state, to exert his voice beyond what is good for him, it may sound rather too like the pot quarrelling with the kettle, and may call for the criticism with which Mr. Tennyson's Princess complimented the disguised Prince on his "Song of the Swallow:"—

> "Not for thee, she said,
> O Bulbul, any rose of Gulistan
> Shall burst her veil: marsh divers rather, maid,
> Shall croak thee sister, or the meadow crake
> Grate her harsh kindred in the grass."

Is it for this, then, that we are to forsake the luncheons and lawn tennis and all the engrossing studies of the May Term, and to assemble in this solemn hall, where the very air seems thick with the accumulation of unsolved problems, or else redolent of the graces of innumerable congregations?

It is not by concentrating our minds on any problem, however important, but rather by encouraging them to expand, that we shall best fulfil the intention of Sir Robert Rede when he founded this lecture.

It would be as useless as it would be tedious to try to explain the various parts of this small instrument to persons in every part of the Senate House. I shall, therefore, consider the telephone as a material symbol of the widely separated departments of human knowledge, the cultivation of which has led, by as many converging paths, to the invention of this instrument by Professor Graham Bell.

For whatever may be said about the importance of aiming at depth rather than width in our studies, and however strong the demand of the present age may be for specialists, there will always be work, not only for those who build up particular sciences and write monographs on them, but for those who open up such communications between the different groups of builders as will facilitate a healthy interaction between them. And in a university we are especially bound to recognise not only the unity of science itself, but the communion of the workers in science. We are too apt to suppose that we are congregated here merely to be within reach of certain appliances of study, such as museums and laboratories, libraries and lecturers, so that each of us may study what he prefers. I suppose that when the bees crowd round the flowers it is for the sake of the honey that they do so, never thinking that it is the dust which they are carrying from flower to flower which is to render possible a more splendid array of flowers, and a busier crowd of bees, in the years to come. We cannot, therefore, do better than improve the shining hour in helping forward the cross-fertilization of the sciences.

Before we go further, I wish to express my obligation to Mr. Garnett for the able assistance he has given me. He has not only collected the apparatus before you, but constructed some of it himself. But for him, I might have given you some second-hand information about telephones. He has made it possible for you to hear something yourselves. I have also to thank Mr. Gower, who has brought his telephone harp, and Mr. Middleton, who has contributed several instruments of his own invention.

We shall begin with the telephone in its most obvious aspect, as an instrument depending on certain physical principles.

The apparatus consists of two instruments, the transmitter and the receiver, doubly connected by a circuit capable of conducting electricity. The speaker talks to the transmitter at one end of the line, and at the other end of the line the listener puts his ear to the receiver, and hears what the speaker says.

The process in its two extreme stages is so exactly similar to the old-fashioned method of speaking and hearing that no preparatory practice is required on the part of either operator.

We must not, however, fall into the error of confounding the principle of the electric telephone with that of other contrivances for increasing the distance at which a conversation may be carried on. In all these the principle is the same as in the ordinary transmission of sound through the air. The different portions of matter which intervene between the speaker and the hearer take part, in succession, in a certain mechanical process. Each receives a certain motion from the portion behind it and communicates a precisely similar motion to the portion in front of it, in doing which it gives out all the energy it received, and is again reduced to rest.

The medium which takes part in this process may be the open air, or air confined in a long tube, or some other medium such as a brick wall, as when we hear what goes on in the next house, or a long wooden rod, or a metal wire, or even a stretched string. In all these it is by the actual motion of the successive portions of the medium that the message is transmitted.

In the electric telephone there is also a medium extending from the one instrument to the other. It is a copper wire, or rather two wires forming a closed circuit. But it is not by any motion of the copper that the message is transmitted. The copper remains at rest, but a variable electric current flows to and fro in the circuit.

It is this which distinguishes the electric telephone from the ordinary speaking tube, and from the transmission of vibrations along wooden rods by which Sir Charles Wheatstone used to cause musical instruments to sound in a mysterious manner without any visible performer.

On the other hand, we have to distinguish the principle of the articulating telephone from that of a great number of electrical contrivances which produce visible or audible signals at a distance. Most of these depend on the alternate transmission and interruption of an electric current. In some part of the circuit a piece of apparatus is introduced corresponding to this instrument which is called a key. Whenever two pieces of metal, called the contact pieces, touch each other, the current flows from the one to the other, and so round the circuit. Whenever the contact pieces are separated the current is interrupted, and the effects of this alternation of current and no current may be made to produce signals at any other part of the circuit.

In the Morse system of signalling, currents of longer and of shorter duration are called dashes and dots respectively, and by combinations of these the symbols of letters are formed. The rate at which these little currents succeed one another depends on the rate at which the operator can work the key, and may be increased by mechanical methods till the receiving clerk can no longer distinguish the symbols.

But the capability of the telegraph wire for transmitting signals is by no means exhausted; as the rapidity of the succession is increased, the ear ceases to distinguish them as separate signals, but begins to recognise the impression it receives as that of a musical tone, the pitch of which depends on the number of currents in a second.

Tuning forks driven by electricity were used by Helmholtz in his researches on the vowel sounds, and the periodically intermittent current which they furnish is recognised as a most valuable agent in physical and physiological research. The tuning forks are of the most massive construction, and the succession of currents goes on with the most inflexible regularity, so that whenever we have occasion to follow the march of a process which takes place in a short time, such as the vibration of a violin string or the twitch of a living muscle, the tuning fork becomes our appropriate timepiece.

Apparatus of this kind, however, the merit of which is its regularity, is quite incapable of adapting itself to the transmission of variable tones such as those of a melody.

The first successful attempt to transmit variable tones by electricity was made by Philip Reis, a teacher in a school at Friedrichsdorf, near Homburg. On October 21, 1861, Reis showed his instrument, which he called a telephone, to the Physical Society of Frankfort on the Main. He succeeded in transmitting melodies which were distinctly heard throughout the room.

The transmitter of Reis's telephone is essentially a make and

break key of so delicate a construction that the sound-waves in the air are able to work it.

The air vibrations set in motion a stretched membrane like a drumhead, with a piece of platinum fastened to it. This piece of platinum, when vibrating, strikes against another piece of platinum, and so completes the circuit every time contact is made.

At every point of the circuit there is thus a series of currents corresponding in number to the vibrations of the drumhead, and by causing these to pass through the coil of an electromagnet, the armature of the electromagnet is attracted every time the current passes, and if the armature is attached to a resonator of any kind, the succession of tugs will set it in vibration, and cause it to emit a sound, the pitch of which is the same as that of the note sung into the transmitter at the other end of the line.

[Mr. Gower here played the "March of the Men of Harlech" on the telephone harp placed in the Geological Museum. The instrument consists of a set of steel reeds worked by percussion, which make and break contact on the battery circuit, of which the primary wire of an induction coil forms part. The receivers are worked by the secondary current. There were four receivers, one of them Prof. Bell's original one, placed in different parts of the Senate-house.]

If the pitch of a sound were the only quality which we are able to distinguish, the problem of telephony would have received its complete solution in the instrument of Reis. But the human ear is so constructed, and we ourselves are so trained by continual practice, that we recognise distinctions in sound of a far more subtle character than that of pitch; and these finer distinctions have become so much more important for the purposes of human intercourse than the musical distinction of pitch, that many persons can detect the slightest variation in the pronunciation of a word who are comparatively indifferent to the variations of a melody.

Now, the telephone of Prof. Graham Bell is an articulating telephone, which can transmit not only melodies sung to it, but ordinary speech, and that so faithfully that we can often recognise the speaker by his voice as heard through the telephone. How is this effected? It is manifest that if by any means we can cause the tinned plate of the receiving instrument to vibrate in precisely the same manner as that of the transmitter, the impression on the ear will be exactly the same as if it had been placed at the back of the plate of the transmitter, and the words will be heard as if spoken at the other side of a tinned plate.

But this implies an exact correspondence, not only in the number of vibrations, but in the type of each vibration.

Now, if the electrical part of the process consisted merely of alternations between current and no current, the receiving instrument could never elicit from it the semblance of articulate speech. If the alternations were sufficiently regular, they would produce a sound of a recognisable pitch, which would be very rough music if the pitch were low, but might be less unendurable if the pitch were high; still, at the best, it would be like playing a violin with a saw instead of a bow.

What we want is not a sudden starting and stopping of the current, but a continuous rise and fall of the current, corresponding in every gradation and inflexion to the motion of the air agitated by the voice of the speaker.

Prof. Graham Bell has recounted the many unsuccessful attempts which he made to produce undulatory currents instead of mere intermittent ones. He had, of course, to give up altogether the method of making and breaking contact. Every method involving impact of any kind, whether between electric contact pieces or between the sounding parts of the instrument, introduces discontinuity of motion, and therefore precludes a faithful reproduction of speech.

In the ultimate form which the telephone in his hands assumed, the electric current is not merely regulated but actually generated by the aërial vibrations themselves.

The electric principle involved in Bell's telephone is that of the induction of electric currents discovered by Faraday in 1831. Faraday's own statement of this principle has been before the scientific world for nearly half a century, but has never been improved upon.

Consider first a conducting circuit, that is to say, a wire which after any number of convolutions returns into itself. Round such a circuit an electric current may flow, and will flow if there is an electromotive force to drive it.

Consider next a line of magnetic force, such a line as you see here made visible by sprinkling iron filings on a sheet of paraffin paper. This line, as Faraday also first showed, is a line returning into itself, or, as the mathematicians would say, it is a closed curve.

Now, if there are two closed curves in space, they must either embrace one another so as to be linked together, or they must not embrace each other.

If the line of force as well as the circuit were made of wire, and if it embraced the copper circuit, it would be impossible to unlink them without cutting one or other of the wires. But the line of force is more like one of Milton's spirits, which cannot

> "In their liquid texture mortal wound
> Receive, no more than can the fluid air."

Now, if the copper circuit or the lines of force move relatively to each other, then in general some of the lines of force which originally embraced the circuit will cease to embrace it, or else some of those which did not embrace it will become linked with it.

For every line of force which ceases to embrace the circuit there is a certain amount of positive electromotive force, which, if unopposed, will generate a current in the positive direction, and for every new line which embraces the circuit there is a negative electromotive force, causing a negative current.

In Bell's telephone the circuit forms a coil round a small core of soft iron fastened to the end of a steel magnet. Now lines of magnetic force pass more freely through iron than through any other substance. They will go out of their way in order to pass through iron instead of air. Hence a large proportion of the lines of force belonging to the magnet pass through the iron core, and, therefore, through the coil, even though there is no iron beyond the core, so that they have to complete their circuit through air.

But if another piece of soft iron is placed near the end of the core it will afford greater facilities for lines which have passed through the core to complete their circuit, and so the lines belonging to the magnet will crowd still closer together to take advantage of an easy passage through the core and the iron beyond it. If then the iron is moved nearer to the core, there will be an increase in the number of such lines, and, therefore, a negative current in the circuit. If it is moved away there will be a diminution in the number of lines, and a positive current in the circuit. This principle was employed by Page in the construction of one of the earliest magneto-electric machines, but it was reserved for Prof. Bell to discover that the vibrations of a tinned iron plate, set in motion by the voice, would produce such currents in the circuit as to set in motion a similar tinned plate at the other end of the line.

It will help us to appreciate the fertility of that germ of science which Faraday first detected and developed if we recollect that year after year he had employed the powerful batteries and magnets and delicate galvanometers of the Royal Institution to obtain evidence of what he all along hoped to discover—the production of a current in one circuit by a current in another, but all without success, till at last he detected the induced current as a transient phenomenon, to be observed only at the instant of making or breaking the primary circuit.

In less than half a century, and by the aid of no second Faraday, but in the course of the ordinary growth of scientific principles, this germ, so barely caught by Faraday, has developed on the one hand into the powerful currents which maintain the illumination of the lighthouses on our coasts; and on the other, into these currents of the telephone which produce an audible effect, though the engine that drives them is itself driven by the tremors of a child's voice.

Prof. Tait has recently measured the absolute strength of these telephone currents. He produced them by means of a tuning fork vibrating in front of the coil of the transmitter. Before the transmitted note ceased to be audible at the other end of the line he measured by means of a microscope the amplitude of the vibrations of the fork.

He then placed a very delicate galvanometer in the circuit and found what deflexion was produced by a measured motion of the fork.

Finally he measured the deflection of the galvanometer produced by a small electromotive force of known magnitude. He thus found that the telephone currents produced an audible effect when reversed 500 times a second, though their strength was no greater than what a Grove's cell would send through a million megohms, about a thousand million times less than the currents used in ordinary telegraphic work.

One great beauty of Prof. Bell's invention is that the instruments at the two ends of the line are precisely alike. When the tin plate of the transmitter approaches the core of its bobbin it produces a current in the circuit, which has also to circulate round the bobbin of the receiver, and thus the core of the receiver is rendered more or less magnetic, and attracts its tin plate with greater or smaller force. Thus the tin plate of the receiver reproduces on a smaller scale, but with perfect fidelity, every motion of the tin plate of the transmitter.

This perfect symmetry of the whole apparatus—the wire in the middle, the two telephones at the end of the wire, and the two gossips at the ends of the telephones—may be very fascinating to a mere mathematician, but it would not satisfy an evolutionist of the Spencerian type, who would consider anything with both ends alike to be an organism of a very low type, which must have its functions differentiated before any satisfactory integration can take place.

Accordingly, many attempts have been made, by differentiating the function of the transmitter from that of the receiver, to overcome the principal limitation to the power of the telephone. As long as the human voice is the sole motive power of the apparatus it is manifest that what is heard at one end must be fainter than what is spoken at the other. But if the vibration set up by the voice is used no longer as the source of energy, but merely as a means of modulating the strength of a current produced by a voltaic battery, then there will be no necessary limitation of the intensity of the resulting sound, so that what is whispered to the transmitter may be proclaimed *ore rotundo* by the receiver.

A result of this kind has already been obtained by Mr. Edison by means of a transmitter in which the sound vibrations produce a varying pressure on a piece of carbon, which forms part of the electric circuit. The greater the pressure, the smaller is the resistance due to the insertion of the carbon, and therefore the greater is the current in the circuit.

I have not yet seen Mr. Edison's transmitter, but the microphone of Prof. Hughes is an application of carbon and other substances to the construction of a transmitter, which modulates the intensity of a battery current in more or less complete accordance with the sound-vibrations it receives. The energy of the sound produced is no longer limited by that of the original sound. All that the original sound does is to draw supplies of energy from the battery, so that a very feeble sound may give rise to a considerable effect. Thus, when a fly walks over the table of the microphone the sound of his tramp may be heard miles off.

Indeed, the microphone seems to open up several new lines of research. We shall have London physicians performing stethoscopic auscultations on patients in all parts of the kingdom. The Entomological Society have recently been much interested by Mr. Wood-Mason's discovery of a stridulating apparatus in scorpions. Perhaps ere long a microphone, placed in a nest of tropical scorpions, may be connected up to a receiver in the apartments of the society, so as to give the members and their musical friends an opportunity of deciding whether the musical taste of the scorpion resembles that of the nightingale or that of the cat.

I have said that the telephone is an instance of the benefit to be derived from the cross-fertilization of the sciences. Now this is an operation which cannot be performed by merely collecting treatises on the different sciences, and binding them up into an encyclopædia. Science exists only in the mind, and the union of the sciences can take place only in a living person.

Now, Prof. Graham Bell, the inventor of the telephone, is not an electrician who has found out how to make a tin plate speak, but a speaker, who, to gain his private ends, has become an electrician. He is the son of a very remarkable man, Alexander Melville Bell, author of a book called "Visible Speech," and of other works relating to pronunciation. In fact, his whole life has been employed in teaching people to speak. He brought the art to such perfection that, though a Scotchman, he taught himself in six months to speak English, and I regret extremely that when I had the opportunity in Edinburgh I did not take lessons from him. Mr. Melville Bell has made a complete analysis and classification of all the sounds capable of being uttered by the human voice, from the Zulu clicks to coughing and sneezing; and he has embodied his results in a system of symbols, the elements of which are not taken from any existing alphabet, but are founded on the different configurations of the organs of speech.

The capacities of this new mode of representing speech have been put to the test by Mr. Alexander J. Ellis, author of "The Essentials of Phonetics," a gentleman who has studied the whole theory of speech acoustically, philologically, and historically. He describes the result in a letter to *The Reader*:—

"The mode of procedure was as follows:—Mr. Bell sent his two sons, who were to read the writing, out of the room—it is interesting to know that the elder, who read all the words in this case, had only had five weeks' instruction in the use of the alphabet—and I dictated slowly and distinctly the sounds which I wished to be written. They consisted of a few words in Latin, pronounced first as at Eton, then as in Italy, and then according to some theoretical notions of how the Latins might have uttered them. Then came some English provincialisms and affected pronunciations, the words 'how odd' being given in several distinct ways. Suddenly German provincialisms were introduced; then discriminations of sounds often confused. Some Arabic, some Cockney English, with an introduced Arabic guttural, some mispronounced Spanish, and a variety of shades of vowels and diphthongs.

"The result was perfectly satisfactory—that is, Mr. Bell wrote down my queer and purposely exaggerated pronunciations and mispronunciations, and delicate distinctions, in such a manner that his sons, not having heard them, so uttered them as to surprise me by the extremely correct echo of my own voice. . . . Accent, tone, drawl, brevity, indistinctness were all reproduced with surprising accuracy. Being on the watch, I could, as it were, trace the alphabet in the lips of the readers. I think, then, that Mr. Bell is justified in the somewhat bold title which he has assumed for his mode of writing—'Visible speech.' I only hope that for the advantage of linguists, such an alphabet may soon be made accessible, and that, for the intercourse of nations, it may be adopted generally, at least for extra-European nations, as for the Chinese dialect and the several extremely diverse Indian languages, where such an alphabet would rapidly become a great social and political engine."

The inventor of the telephone was thus prepared, by early training in the practical analysis of the elements of speech, to associate whatever scientific knowledge he might afterwards acquire with those elementary sensations and actions, which each of us must learn from himself, because they lie too deep within us to be described to others. This training was put to a very severe test when, at the request of the Boston Board of Education, Prof. Graham Bell conducted a series of experiments with his father's system in the Boston School for the Deaf and Dumb. I cannot conceive a nobler application of the scientific analysis of speech, than that by which it enables those to whom all sound is

> "expunged and rased
> And wisdom at one entrance quite shut out"

not only to speak themselves, but to read by sight what other people are saying. The successful result of the experiments at Boston is not only the most valuable testimonial to the father's system of visible speech, but an honour which the inventor of the telephone may well consider as the highest he has attained.

An independent method of research into the process of speech was employed by Wheatstone, Willis, and Kempelen, the aim of which was to imitate the sounds of the human voice by means of artificial apparatus. This apparatus was in some cases modelled so as to represent as nearly as possible the form as well as the functions of the organs of speech, but it was found that an equally good imitation of the vocal sounds could be obtained from apparatus the form of which had no resemblance to the natural organs.

Several isolated facts of considerable importance were established by this method, but the whole theory of speaking and hearing has been so profoundly modified by Helmholtz and Donders, that much of what was advanced before their time has come to possess only an historical interest.

Among all the recent steps in the progress of science, I know none of which the truly scientific or science-producing consequences are likely to be so influential as the rise of a school of physiologists, who investigate the conditions of our sensations by producing on the external senses impressions, the physical conditions of which can be measured with precision, and then recording the verdict of consciousness as to the similarity or difference of the resulting sensations.

Prof. Helmholtz, in his recent address as Rector of the University of Berlin, lays great stress on that personal interaction between living minds, which I have already spoken of as essen-

tial to the life of a University. "I appreciate," he says, "at its full value this last advantage, when, looking back, I recall my student days, and the impression made upon us by a man like Johannes Müller, the physiologist. When one finds himself in contact with a man of the first order, the entire scale of one's intellectual conceptions is modified for life; contact with such a man is perhaps the most interesting thing life may have to offer."

Now, the form in which Johannes Müller stated what we may regard as the germ which fertilized the physiology of the senses is this, that the difference in the sensations due to different senses does not depend upon the actions which excite them, but upon the various nervous arrangements which receive them.

To accept this statement out of a book, as a matter of dead faith, may not be difficult to an easy-going student; but when caught like a contagion, as Helmholtz caught it, from the lips of the living teacher, it has become the guiding principle of a life of research.

No man has done more than Helmholtz to open up paths of communication between isolated departments of human knowledge; and one of these, lying in a more attractive region than that of elementary psychology, might be explored under exceptionally favourable conditions, by some of the fresh minds now coming up to Cambridge.

Helmholtz, by a series of daring strides, has effected a passage for himself over that untrodden wild between acoustics and music—that Serbonian bog where whole armies of scientific musicians and musical men of science have sunk without filling it up.

We may not be able even yet to plant our feet in his tracks and follow him right across. That would require the seven league boots of the German colossus; but to help us in Cambridge we have the Board of Musical Studies, vindicating for music its ancient place in a liberal education. On the physical side we have Lord Rayleigh laying the foundation deep and strong in his "Theory of Sound." On the æsthetic side we have the University Musical Society doing the practical work, and in the space between, those conferences of Mr. Sedley Taylor, where the wail of the siren draws musician and mathematician together down into the depths of their sensational being, and where the gorgeous hues of the phoneidoscope are seen to seethe and twine and coil like the

"Dragon boughs and elvish emblemings"

on the gates of that city where

"an ye heard a music, like enow
They are building still, seeing the city is built
To music, therefore never built at all,
And therefore built for ever."

The special educational value of this combined study of music and acoustics is that more than almost any other study it involves a continual appeal to what we must observe for ourselves.

The facts are things which must be felt; they cannot be learned from any description of them.

All this has been said more than two hundred years ago by one of our own prophets—William Harvey, of Gonville and Caius College. "For whosoever they be that read authors, and do not by the aid of their own senses, abstract true representations of the things themselves (comprehended in the author's expressions) they do not resent true ideas, but deceitful idols and phantasms, by which they frame to themselves certain shadows and chimæras, and all their theory and contemplation (which they call science) represents nothing but waking men's dreams and sick men's phrensies."

Prof. Maxwell was assisted in his practical demonstrations by Mr. Garnett, of St. John's College.

SOCIETIES AND ACADEMIES

London

Physical Society, April 13.—Prof. R. B. Clifton, vice-president, in the chair.—The following candidates were elected Members of the Society:—W. Campbell, R. W. F. Harrison, Rev. T. N. Hutchinson, M.A., B. W. Richardson, M.B., F.R.S.—The Secretary read a paper by Messrs. J. Nixon and A. W. Heaviside, describing their experiments on the mechanical transmission of speech through wires or other substances, to which Mr. Preece had referred at a previous meeting of the Society. After describing a number of experiments in which metallic discs soldered on to the ends of the conducting wires were employed, they went on to enumerate the more successful experiments in which wooden discs were mainly employed. The first actual transmission of speech was effected by placing the belly of a violin against the receiving end of the wire, when every syllable spoken was distinctly audible. Very good results were obtained by employing mouth-and-ear pieces, formed as in a telephone, the disc being replaced by thin wooden discs, six inches in diameter, and a No. 4 wire was found to be most satisfactory. On suspending a length of this wire in such a manner that it had no rigid attachments, it was ascertained that 120 yards is the limit through which a conversation can be carried on.—Capt. Abney, F.R.S., described the method he adopted for photographing the least refrangible end of the spectrum. He pointed out that it is impossible, with the ordinary sensitive salts employed in the usual way, to photograph further than the Fraunhofer line E, though by a preliminary exposure to light of a Daguerrotype plate, Draper was able to photograph beyond the extreme limit of visibility in the red end of the spectrum. This method, however gave what is known as a reversed picture, the lights and shades being transposed, besides requiring a lengthened exposure. It enabled Becquerel to photograph the spectrum in its natural colours, and later St. Victor obtained coloured images of coloured cloths. The object of Capt. Abney had been to obtain unreversed pictures of this portion of the spectrum; in other words, to obtain a compound that would be similarly sensitive to the red and the blue components of white light. Such a compound he had at last obtained by what he termed *weighting* silver bromide with resin, and now he obtains it by causing the molecules of silver bromide to weight themselves. He showed an ordinary bromide of silver plate, and the colour of the transmitted light was of a ruddy tint, showing absorption of the blue rays; another film was shown containing weighted bromide of silver, which transmitted blue light and absorbed the red. Photographic plates prepared with the latter compound he showed were sensitive to the red and ultra-red waves of light, and he threw on the screen photographs of the spectrum from the line C to a wave-length of 10,000, the ultra-red showing remarkable groupings of lines. He further showed that by friction the blue film was changed to the red, and in that state was not sensitive to the lower part of the spectrum. These photographs were taken by means of a diffraction grating, and Capt. Abney demonstrated Fraunhofer's method of separating the various orders of spectra produced by it. He then explained that recently he had elucidated the reason of the reversal of Draper's pictures by the least refrangible end of the spectrum. He finds that it is accelerated by exposing the plates in weak oxidising solutions, such as those of hydroxyl, bichromate of potash, permanganate of potash, and nitric acid, or exposure to ozone. The red rays, in other words, seemed to oxidise the photographic image, and to render it incapable of development.—Mr. H. Bauermathen exhibited some paper models illustrative of the disposition of the planes of symmetry in crystals. These included octants of the sphere with inclosed cube and octahedron faces pointed into their corresponding hexakis-octohedral faces, a cubic skeleton built up from nine planes of symmetry with a removable outer shell, and a system of axial planes of an unsymmetrical mineral inclosing a solid nucleus contained between three parallel pairs of planes. They were constructed for the purpose of showing popularly the difference between planes of symmetry and other diametral planes by laying upon them a small mirror or plate of mica, when in the first case the inclosed nucleus gave a symmetrical image corresponding in position to the plane immediately behind the mirror, but in the second a broken image is produced.—Dr. Guthrie exhibited the arrangement of apparatus he had employed, in conjunction with his brother, to ascertain the effect of heat on the transpiration of gases. The main difficulty connected with the research was the securing of an absolutely constant pressure on the air operated upon. This was secured by inserting into the neck of the vessel which served as an air-chamber a tube turned up at its inner end and terminating externally by a small funnel; as the tube was kept constantly full of water, the funnel overflowing, a pressure represented by the difference between the heights of these levels was maintained. After passing through a series of drying tubes the air traversed the (U-shaped) capillary tube in a beaker containing water of known temperature, and was finally received in an inverted tube contained in an overflowing dish of water. Among other results it was found that the resistance of a tube is the same as that of its several portions,